CITIZEN SCIENCE: THEORY AND PRACTICE

Context – Goal – Method – Outcome: Alignment in Citizen Science Project Design and its Relation to Supporting the United Nations Sustainable Development Goals

COLLECTION: CONTRIBUTIONS OF CITIZEN SCIENCE TO THE UN SDGS

RESEARCH PAPER

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ABSTRACT

Citizen science (CS) is a diverse practice, with projects emphasizing scientific and/ or democratization goals. While the integration of both goals is advocated for sustainability transitions, this implies contextualized methodological choices.

This contribution presents an instrument to explore methodological choices in relation to project goals and context, linking these patterns to the United Nations Sustainable Development Goals (SDGs). By way of a PRISMA scoping review, case studies implemented in the Global North (GN) or Global South (GS) were selected and categorized using the instrument to identify notable patterns. GN projects are generally published by GN authors and can predominantly be linked to productivity goals relating to SDGs on biodiversity (SDGs 14, 15). In contrast, GS projects are commonly associated with diverse co-author groups that focus on democratization and/ or productivity, and prioritize SDGs on agriculture, health, sustainable communities, and climate change (SDGs 2, 3, 11, 13). The analyzed case studies could contribute directly to three SDG indicators and indirectly to 22.

Methodological choices regarding project goals and themes translate into variations in participant selection and recruitment, contribution types, and project outcomes. Further, project design and outcomes can be linked to co-authorships, with larger teams typically associated with co-created projects which in turn focus on democratization or democratization and productivity goals, and produce a wide diversity of outcomes.

Qualitative information extracted from the investigated papers was used to contextualize the relevance of combining productivity and democratization goals as well as the related challenges of harmonizing different interests and of resource limitations as well as other project constraints.

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INTRODUCTION

Citizen science (CS), public participation in scientific projects, is characterized by diverse definitions (Haklay et al. 2021), with no single term appropriate for all contexts (Eitzel et al. 2017). While this diversity results in a large range of desired outcomes (Kimura and Kinchy 2016), CS can be broadly classified into two streams: the democratization stream, which emphasizes empowerment and science's responsibility to society; and the productivity stream, which emphasizes society's data collection capacity and potential contributions to scientific research (Eitzel et al. 2017; Sauermann et al. 2020). In practice, nuances exist, and while some projects focus on a unique goal, others combine both productivity and democratization goals.

The potential of CS to support the United Nations Sustainable Development Goals (SDGs) has been reported (Fritz et al. 2019; Fraisl et al. 2020; Pateman, Tuhkanen, and Cinderby 2021). For example, monitoring data can be collected with productivity approaches (West and Pateman 2017; Fritz et al. 2019), while democratization approaches could support contextualizing SDG agendas (West and Pateman 2017). As such, citizens can contribute with techno-scientific and socio-political knowledge relevant for sustainability transitions, given their cross-cutting nature (Sauermann et al. 2020).

When designing CS projects combining both goals, trade-offs arise. For instance, participant diversity is key to representing the broader population in democratization projects, while some productivity projects request participants to have certain skills limiting the accessibility (Sauermann et al. 2020). Other compromises relate to balancing the benefits of large-scale data collection against opportunities for close interaction between researchers and community members (Berkes 2004; Evans et al. 2005; Shirk et al. 2012; Sauermann et al. 2020). Therefore, research on goal trade-offs and on mechanisms to better accomplish scientific and non-scientific goals is needed (Sauermann et al. 2020).

Despite the growing body of CS literature, studies are mainly concentrated in Europe and North America (Cunha et al. 2017; Vasiliades et al. 2021), and limited information about collaboration networks exists (Pelacho et al. 2021). Research on partnerships between the Global North (GN) and Global South (GS) suggests persistent knowledge inequalities (Collyer 2018), and to shift power towards implementation countries, Genda et al. (2022) recommends closer collaborations between local and international scientists. In this matter, CS could contribute towards democratizing knowledge production, especially in historically under-represented contexts (Ramos Carvalho et al. 2022). Although collaboration in CS is gaining research interest (Pelacho et al. 2021), insights into how authorship links to case study properties such as implementation context, topic, or methodological choices is lacking.

Further, CS research often focuses on particular aspects such as participant profile and motivation (Pateman, Dyke, and West 2021; West, Dyke, and Pateman 2021), degree of participation (Shirk et al. 2012; Sauermann et al. 2020; Vasiliades et al. 2021), impact (Wehn et al. 2021), or contextual considerations (Eitzel et al. 2017). Although some frameworks elaborate on the links between these aspects, such as participant motivation and the type of contribution (Lotfian, Ingensand, and Brovelli 2020), only a few projects focus on understanding CS as a field. Notable examples include the CS Track (De-Groot et al. 2022) and the Measuring Impact of Citizen Science (MICS) project (Parkinson et al. 2022), which map the CS landscape, providing tools to analyze projects as well as identify their impact and potential contribution to the SDGs.

While these frameworks describe CS from different angles, there is a need for representing CS components and the connections between them, analyzing methodological aspects in an integrative way and relating them to other variables such as context and potential contribution to the SDGs.

In this contribution, an instrument is presented to examine project design characteristics in relation to context and project goals. The application of this instrument is illustrated based on a Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA) scoping review, utilizing selected CS case studies implemented in either the GN or GS. These case studies are analyzed to understand: 1) co-authorship patterns and their relation to methodological choices; 2) patterns between project design characteristics and project goals as well as their context dependency; and 3) the CS contribution to the SDGs and whether this links to methodological choices. As such, the results of this analysis provide some insight into the rationales underlying the design of CS projects and could be a first step in identifying best practices in integrative CS contributing to the SDGs.

METHODS

The literature review leading to instrument construction is presented first. The application of the instrument to CS case studies is then described, followed by an explanation on the performed analysis.

LITERATURE REVIEW AND INSTRUMENT CONSTRUCTION

An exploratory literature review was performed through Google Scholar, dividing the search into articles on CS diversity and contextual perspectives; frameworks, meta-analyses, and literature reviews on CS project design; and the (potential) CS contribution to SDGs. The findings were complemented with publications extracted from

Web of Science (WoS), inserting ["citizen scien*"] AND [framework*] in the WoS category [all fields], searching all of the searchable fields using one query.

Building on literature findings, an instrument was developed to characterize the case studies. This instrument is intended not to replicate earlier frameworks describing separate dimensions (e.g., context, methods, or goals), but rather to compile their elements into a tool linking these dimensions. To achieve this, the compiled articles were reviewed and a CS dimensions list was elaborated based on project features explicitly or implicitly present in the papers. Subsequently, each dimension was characterized through a definition of categories, based on literature review insights.

The instrument was tested in various iterative rounds categorizing case studies, and after each round, categories were revised depending on their interpretability.

CASE STUDIES SELECTION

The PRISMA method was used for case studies selection as it is a standardized protocol for systematic reviews (Tricco et al. 2018). It has been previously used in the CS field (Wehn et al. 2021), and here it was used together with a Population, Concept, and Context (PCC) framework (Peters et al. 2020) for defining inclusion and exclusion criteria (Supplemental File 1: Appendix A).

The scoping review compiles CS case studies implemented either in a GN or a GS country. Although the division of countries according to their economic development (Odeh 2010) limits the representation of all heterogeneities within these two groups, it allows the extraction of context-specific patterns in CS design and in the potential contribution to the SDGs.

A literature search was conducted in the core collection of WoS on 9 September 2022. While some authors recommend using at least two databases (Hansen, Steinmetz, and Block 2021), only one was selected since the intention of this study was not to build an exhaustive database, but rather to build a database containing implementations in GS and GN countries to deduct design patterns.

English language case study articles published between 03/03/2019 and 03/03/2022 were extracted from WoS. To identify case study articles, document type "article" and topic "case" were selected, including articles mentioning the term "case" in their title, keywords, or abstract. To identify case studies on CS, a second criteria was introduced to the topic, that is, keywords referring to the concept of CS. These were selected when mentioned in at least two of the three following publications that present different terminologies in the CS field: Kullenberg and Kasperowski (2016), Piland et al. (2020), and Wehn et al. (2021).

Searches with the abovementioned criteria were conducted twice, each time including an additional topic criterion with a list of either GS (Finance Center for South-South Cooperation 2015; World Population Review 2022) or GN countries (World Population Review 2022) (Supplemental File 2: Appendix B). Although searches were constrained to case studies where the country was mentioned in either the title, abstract, or keywords, this allowed locating papers to analyze the case studies' designs in different geographic contexts. The search strings are summarized in Supplemental File 3: Appendix C.

Compilations for GS and GN countries were exported from WoS and imported to Rayyan, a web and mobile app for systematic reviews (Ouzzani et al. 2016). Rayyan was used to screen the abstracts, accepting those that complied with the inclusion criteria. Included papers were then fully reviewed and retained according to the inclusion/exclusion criteria.

Since the instrument was designed to understand design choices in CS case studies, the following categories were excluded: meta-analyses, protocols, reviews and papers comparing two or more case studies; papers reflecting on CS data but not describing the project itself; projects in which participants themselves are the subject of the study or do not actively participate; control trials; and projects involving citizens in research through interviews, surveys, and/or focus groups, unless these techniques were used to collaboratively elaborate research questions and/or scientific methodologies (Supplemental File 1: Appendix A).

The inclusion-exclusion process as well as the number of case studies identified, screened, and selected are detailed in the PRISMA flow diagram (Supplemental File 4: Appendix D).

INSTRUMENT IMPLEMENTATION: ANALYSIS OF CASE STUDIES

Included publications were classified according to the instrument, with each case study representing a row-entry with project features inserted in the columns. Additionally, annotations on project design trade-offs discussed by the case study authors were collected.

Each case study was screened for potential contributions to the SDGs based on SDG targets, indicators, and metadata (United Nations Statistics Division 2023). The contribution of each case study to one or more indicators was identified and classified into: 1) direct contributions, in which the collected data matches the metadata requirements; or 2) indirect contributions, in which required metadata cannot be fulfilled but the case study could benefit a SDG indicator (detailed in Supplemental File 5: Appendix E). In this study, SDG 17, "Partnerships for the goals," was not included because although CS brings different stakeholders together (Pateman, Tuhkanen, and Cinderby 2021), the complexity of building partnerships for the goals constitutes a study on its own. The collected data was analyzed with the open-source software R, extracting patterns in design choices. This analysis was complemented and contextualized by a qualitative description of case study authors' experiences.

RESULTS

This section is divided into three subsections: literature review outcomes, the elaborated instrument, and the results of the analysis of case studies.

LITERATURE REVIEW OUTCOMES

This section summarizes the literature review outcomes, in addition to the five identified dimensions that collectively characterize CS projects.

Context

The dimension of context is relevant given the geographic imbalance of case studies, characterized by the underrepresentation of Africa, Asia, Latin America, and Oceania (Cunha et al. 2017; Vasiliades et al. 2021), as well as the influence of resource limitations on CS practices, including the lack of national funding schemes (Cunha et al. 2017; Vasiliades et al. 2021), limited internet access (Cunha et al. 2017), and socio-political factors (Stevens et al. 2014; Vasiliades et al. 2021). As such, the link between implementation location and other dimensions, as defined in Figure 1, are investigated in this study. In addition, the

Figure 1 Visualization of citizen science (CS) dimensions (context, goal(s), methods, outcome, and contribution to the SDGs), and their relationships.

(co)authors' country affiliations were analyzed because despite the relevance of investigating heterogeneity among scientists (Sauermann et al. 2020), research on co-authorship networks in the CS field is still limited (Pelacho et al. 2021). In this field, Cunha et al. (2017) expose a link between project initiators and goal formulation, and Pelacho et al. (2021) analyze collaboration network evolution, but heterogeneity of the co-author team affiliation in relation to implications on project methods and results remains unexplored. This deserves attention in order to understand how collaborative research brings diverse knowledge together, considering the inherent complexities of multidisciplinary research groups (Wray 2006).

Goal

The design of CS projects is inspired by project goals, and these tend to focus on data collection or on democratization aspects such as education and empowerment. Although the combination of both goals is possible (and desirable in addressing complex issues), trade-offs between goals must often be made (Shirk et al. 2012; Chase and Levine 2016). Overall, the selected goals reflect addressed interests, and in this regard, accommodating the participants and the scientific community interests is essential (Shirk et al. 2012). The analysis of alignment between goal setting and methods-specific design is elaborated below.

Methods

The methods dimension encompasses the different degrees of participation, the type of participant contribution, and participant profile as well as the methodological implications of such decisions. The degrees of participation include: 1) contributory projects, whereby participants collect data; 2) collaborative projects, in which participant contributions go beyond data collection, for example, analyzing data, and/or disseminating results; and 3) co-created projects, designed collaboratively by scientists and participants (Shirk et al. 2012; Sauermann et al. 2020; Vasiliades et al. 2021).

The degree of participation can be closely linked to project goals, for example, contributory projects that rely on volunteers as "data collectors" without necessarily considering democratization aspects (Vasiliades et al. 2021). In turn, the link between goals and degree of participation is expected to translate into specific participant profiles. While some projects require specific physical or technical skills to achieve their goals (Chase and Levine 2016; Cunha et al. 2017), others target participant diversity or inclusion of underrepresented groups (Pateman, Dyke, and West 2021).

Overall, implemented methods are likely to reflect on the outcomes. For example, co-created projects have been demonstrated to impact policy decisions, while scientific knowledge outcomes are most common in contributory projects (Wilderman and Shirk 2010).

Outcomes/impact

The high expectations of CS contrast with the few instances in which CS impact is measured and reported (Wehn et al. 2021), despite the recent tools development for measuring five impact domains: society, economy, environment, science and technology, and governance (Somerwill and Wehn 2022). This could be attributed to the fact that while outcomes can be measured within one to three years of project implementation, long-term impacts such as those benefitting human well-being or natural resource conservation might need longer before being noticeable (Kellogg Foundation 2004; Shirk et al. 2012). Since measured impact is rarely detailed, the category "impact" was not included in the instrument. Instead, outcomes of the case studies were collected, including all reported results identified in the case studies, with the category "data" including quantitative and qualitative scientific data. This approach allows the study of alignment between proclaimed goals and reported outcomes, facilitating as well identifying the outcomes' contributions to the SDGs.

(Potential) CS contribution to SDGs

The potential of CS to address data gaps in various SDG indicators has been supported by the large spatial dimensions and broad spectrum of themes that CS covers (Fritz et al. 2019). Fraisl et al. (2020) assert that CS is already contributing to monitoring five indicators and could contribute to 76 indicators. However, although CS projects could potentially contribute to all 17 goals in low- and middle-income countries, currently no projects specifically collect SDG monitoring data (Pateman, Tuhkanen, and Cinderby 2021). The added value of monitoring SDGs through CS in countries with limited human and economic resources is well accepted (Fritz et al. 2019), but research evidencing the actual contribution and knowledge gaps is needed.

The five CS dimensions qualitatively described above, are summarized in Figure 1. This visualization presents the relationships explored through the application of the instrument, as described below, to the databases on GN and GS case studies.

INSTRUMENT

The literature review findings were compiled in the instrument: the five identified dimensions—context, goal, methods, outcome, SDGs—are further specified through subdivisions and their respective classifiers (Figure 2). Project goals were characterized based on how they are framed: When the framing is purely scientific (e.g., collect data) without societal goals formulation, the goal is classified as "Productivity;" when societal goals are described (e.g., education or improvement of livelihoods), and no scientific goals are defined, the goal is classified as "Democratization;" and when the project's goals are framed identifying both societal and scientific goals, the goal is classified as "Productivity and democratization." Only obtained results explicitly mentioned by the authors (e.g., data and research protocols) were considered as identified outcomes, and not those speculated, such as potential contribution to awareness-raising or policies. In terms of participant profile, "Affected community member" is defined as member(s) of a community affected directly by a hazard (e.g., flooding), or indirectly (e.g., farmers potentially impacted by climate change). "Community member with a particular profile or skill" is defined as participants who are, due to their profession or skills, uniquely positioned to contribute to the project.

RELATIONSHIPS BETWEEN THE CITIZEN SCIENCE DIMENSIONS

This section presents the results of the explored relationships between the CS dimensions (arrows in Figure 1). In total, 55 case studies were analyzed, of which 29 were implemented in the GN and 26 in the GS.

Linking context (implementation location) with goals/SDGs

In total, four case studies could directly contribute to monitoring SDG indicators: one implemented in the GS on municipal solid waste data (indicator 11.6.1); and three in the GN, two of which relate to marine debris data (indicator 14.1.1) and one on the contribution of "exotic species" data to legislation (indicator 15.8.1). Only productivity outcomes could directly be linked to SDG indicators (predominantly in GN projects), while some democratization projects could indirectly contribute to the indicators with others contributing only to the target. From the 55 case studies, 41 case studies could indirectly contribute to a total of 22 indicators, with 14 case studies not linked to any indicators. The results below focus on SDGs 1 to 16.

The link between context and goals and the (in)direct contributions to the SDGs (relationship visualized by arrow 1 in Figure 1) as observed from the case studies' analysis is shown in Figure 3. In the GN, SDG contributions are most common for biodiversity SDGs (SDGs 14 and 15), stemming from projects with a productivity goal. Next, the most mapped indicators in the GN relate to sustainable communities (SDG 11) and education (SDG 4). In contrast, the SDG zero hunger (SDG 2) is most mapped in GS

Context [a]			Goal [b]
1st Author location	Co-author(s) location	Implementation location	Goal
Choose 1 from Standardized country list *Mapped to GN or GS*	**Choose multiple** Standardized country list *Mapped to GN, GS or Mix*	**Choose 1 from** Standardized country list *Corresponding to GN or GS case studies*	**Choose 1 from** Productivity Democratization Productivity and democratization

Methods				
Thematic focus [c]	Contribution [d]	Degrees of participation [e]	Participant selection [f]	Participants profile [f]
Choose 1 from Agriculture Ecology Education Hazards / risk Health Heritage Inclusiveness Waste / pollution / environment Water resources	**Choose multiple** Design research questions Design methods Collect data Analyze data Science communication Protect / install instruments	**Choose 1 from** Contributory Collaborative Co-created	**Choose 1 from** Self-selection Deliberate productivity Deliberate democratization Deliberate productivity / democratization Selected by community Not described	**Choose 1 from** Affected community member Community member particular profile or skill General community member Teacher / student Combination

Outcome [g]
Outcome
Choose multiple Data Empowerment Infrastructure Learning outcomes Network Policy Research protocol Socio-environmental improvement Teaching material

SDGs [h]		
SDG target	SDG indicator - direct	SDG indicator - indirect
Choose multiple SDG targets [i]	**Choose multiple** SDG indicators [i]	**Choose multiple** SDG indicators [i]

Figure 2 Instrument representing the five dimensions, the subdivisions and their respective classifiers. **a)** Cunha et al. 2017; Vasiliades et al. 2021. **b)** Shirk et al. 2012; Chase and Levine 2016; Cunha et al. 2017; Sauermann et al. 2020. **c)** Inspired by Kullenberg and Kasperowski 2016; Turbé et al. 2019; De-Groot et al. 2022 with modifications based on identified themes. **d)** and **e)** Based on Shirk et al. 2012; Sauermann et al. 2020; Vasiliades et al. 2021, with additions to category "contribution" based on case studies. **f)** Keywords summarize the content provided by Gillett et al. 2012; Chase and Levine 2016; Cunha et al. 2017; Pateman, Dyke, and West 2021. **g)** Category based on the identified case studies outcomes. **h)** West and Pateman 2017; Fraisl et al. 2020; Pateman, Tuhkanen, and Cinderby 2021; Parkinson et al. 2022. **i)** United Nations Statistics Division 2023.

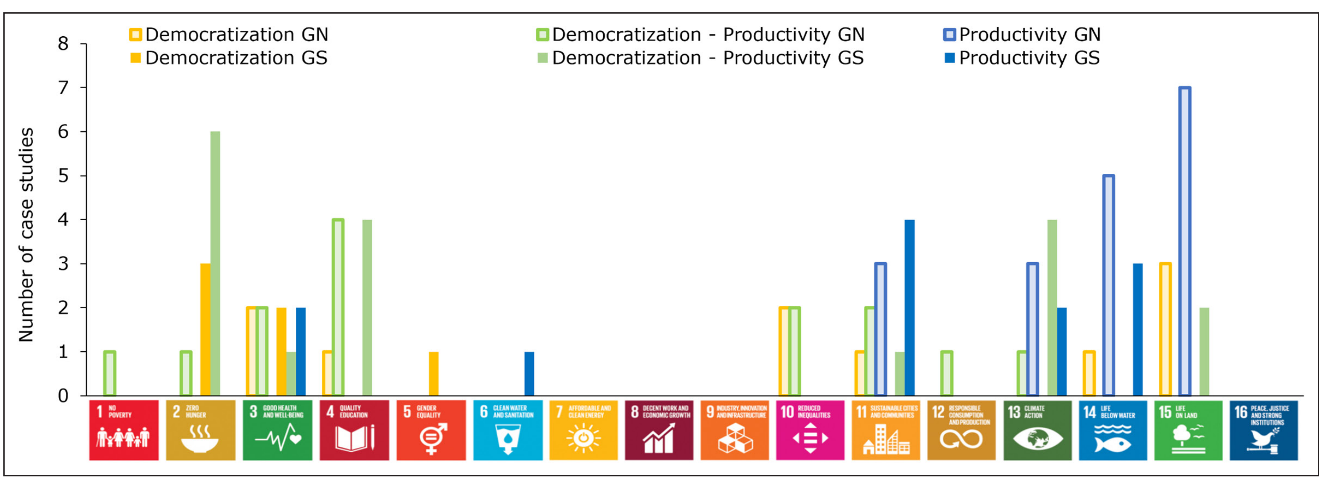

Figure 3 Case studies linked to SDGs according to implementation location and goals. GS: Global South, GN: Global North. SDG 17 is not included in this study.

countries through projects with mixed goals. Following this, the most mapped indicators in the GS relate to health (SDG 3), climate change (SDG 13) and sustainable cities (SDG 11). Both in the GN and GS, education-related projects (SDG 4) aim for productivity and democratization goals.

In general, productivity goals seem to be pursued in planetary health–related projects, and democratization or combined goals are mostly applied to projects related to social aspects (e.g., inclusiveness), human health, and education.

Linking context (authorship and implementation location) with methods

A noticeable difference between co-author teams in the GS and GN is evident (Figure 4). With regard to projects implemented in the GS, co-author partnerships are more diverse. Out of 26 analyzed case studies, 10 were conducted by a team solely from the GS, and 4 case studies with co-authors solely from the GN. By comparison, 28 out of 29 case studies in GN countries were composed by an exclusively GN author team. This also translates in the number of unique countries involved in publications on the basis of the authors' affiliations, with more than half of the projects in the GS including authors from two or more countries, while in the GN, most contributions (21 of 29) stem from authors within a single country (Figure 5a).

In contrast to the number of unique countries involved, there does not appear to be a significant difference between the overall size of the co-author teams between projects in the GS (mean = 6.4) and GN (mean = 7) (Figure 5b).

However, the size of co-author teams does appear to be related to the degree of participation, with co-created projects characterized by larger co-author teams than collaborative and contributory case studies (Figure 5c; $p < 0.05$, Kruskal-Wallis test). This pattern remains visible regardless of implementation location and project goal although this further subdivision often leads to loss of significance (Supplemental File 6: Appendix F, Figure 2).

Linking project goals and methods design

The linkage between project goals and methods design (relationship visualized by arrow 2 in Figure 1) as observed from the case studies' analysis is made through Figures 6

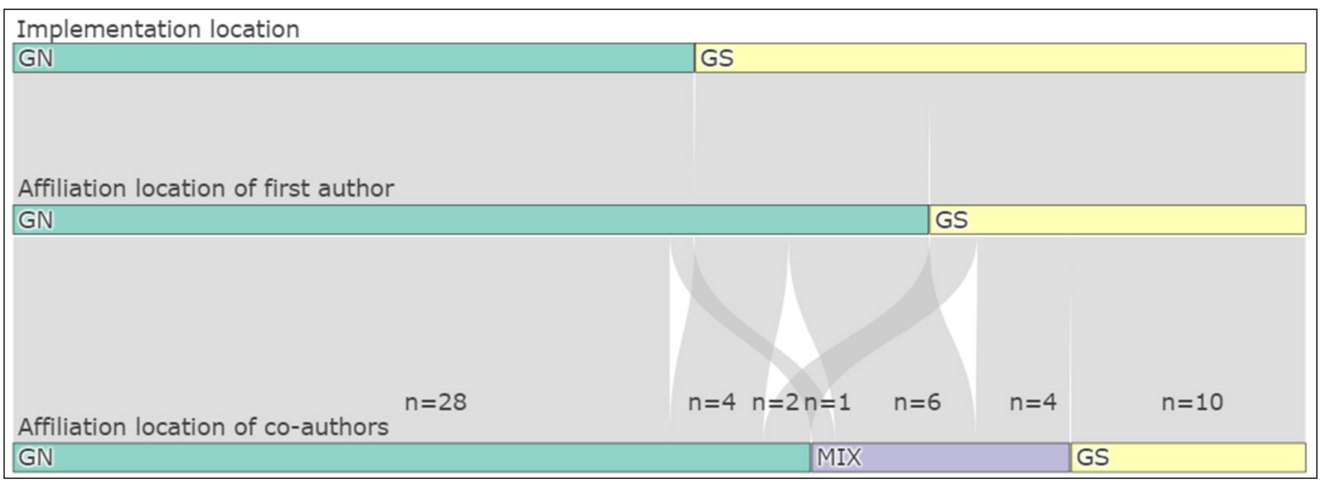

Figure 4 Authorship based on 1st author and co-author affiliation location for implementations in the Global South (GS) and Global North (GN).

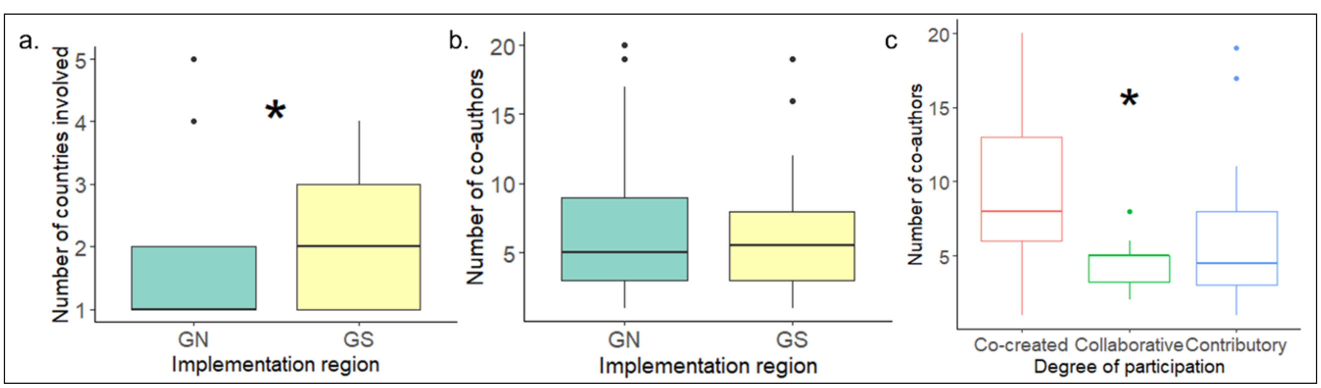

Figure 5 (a) the number of countries involved (according to co-author affiliation) for each implementation region (* = $p < 0.05$, Kruskal-Wallis test), **(b)** the number of co-authors involved for each implementation region ($p > 0.05$, Kruskal-Wallis test), and **(c)** number of co-authors according to degree of participation (* = $p < 0.05$, Kruskal-Wallis test).

and 7. In the GN, there is a strong alignment between project goals and the recruitment method, with democratization goals or combined goals linked to deliberate democratization or deliberate democratization-productivity recruitment (Supplemental File 6: Appendix F, Figure 1a). For productivity goals, the most common recruitment methods are self-selection or "not specified." In terms of participant profile, no majority groups were found in the GN, but distinct ties exist for general community members (most often self-selection) and community members with particular profiles (deliberate productivity) (Supplemental File 6: Appendix F, Figure 1a). This is somewhat contrasted with the patterns in the GS, where alignment between the goals and the recruitment method is more intricate, and where affected community members and community members with a particular profile or skill are most often the target audience (Supplemental File 6: Appendix F, Figure 1b).

Combining GN and GS case studies, it was observed that productivity projects follow predominantly contributory modes of participation, and democratization projects are mostly collaborative and co-created, while different types of participation were observed in projects combining productivity and democratization goals (Figure 6).

Linking project goals with outcomes

Identified outcomes per proclaimed goals in the GN and GS (relationship visualized by arrow 3 in Figure 1) as observed from the case studies' analysis is presented in Figure 7. Data is the most common outcome for projects with productivity goals and for projects with combined goals in both the GN and GS (Figure 7). Outcomes such as empowerment and socio-environmental improvements are less reported and are linked mostly to cases in the GS. Learning outcomes are found in both contexts.

Combining GN and GS case studies, contributory projects tend to have a smaller number of unique outcomes (Figure 8a). Regardless of the degree of participation, data is the most reported outcome (Figure 8b–d). The other most common outcomes are research protocols, learning outcomes, socio-environmental improvement, and networks.

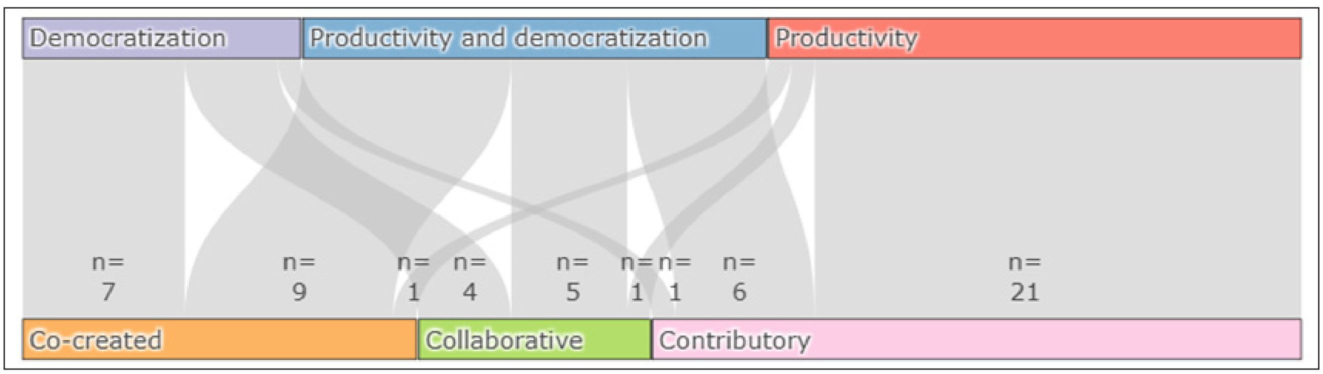

Figure 6 Goals' influence on the degree of participation.

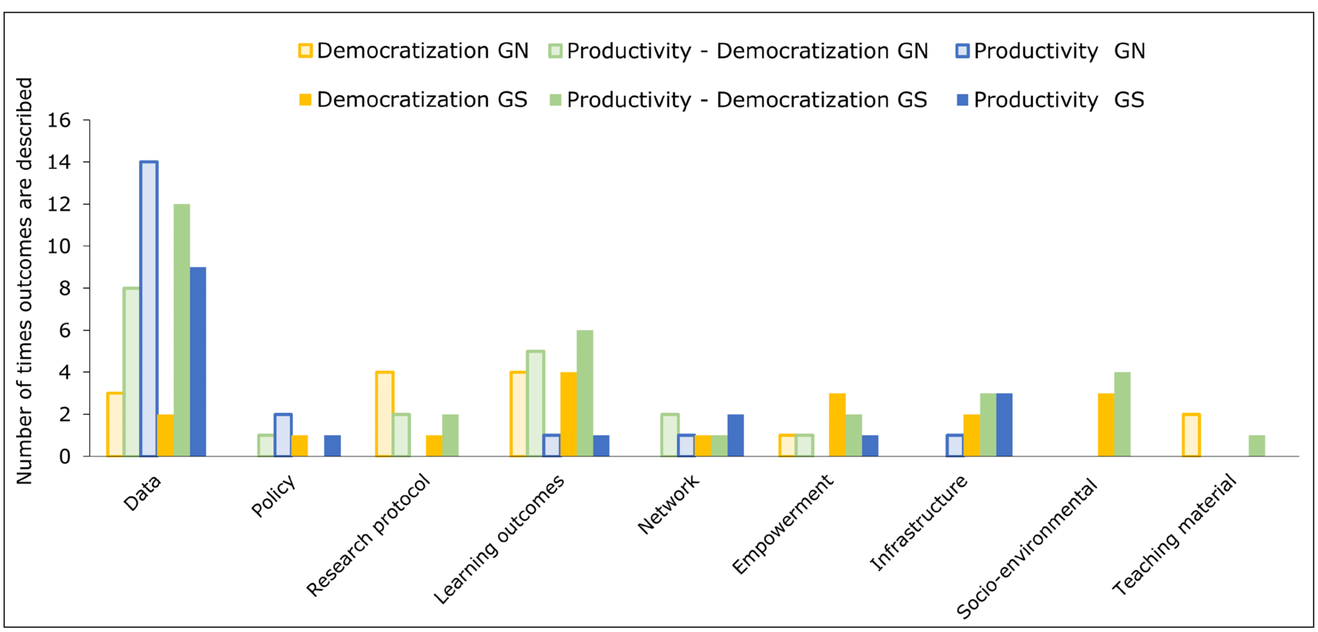

Figure 7 Outcomes per goal in the Global North (GN) and Global South (GS).

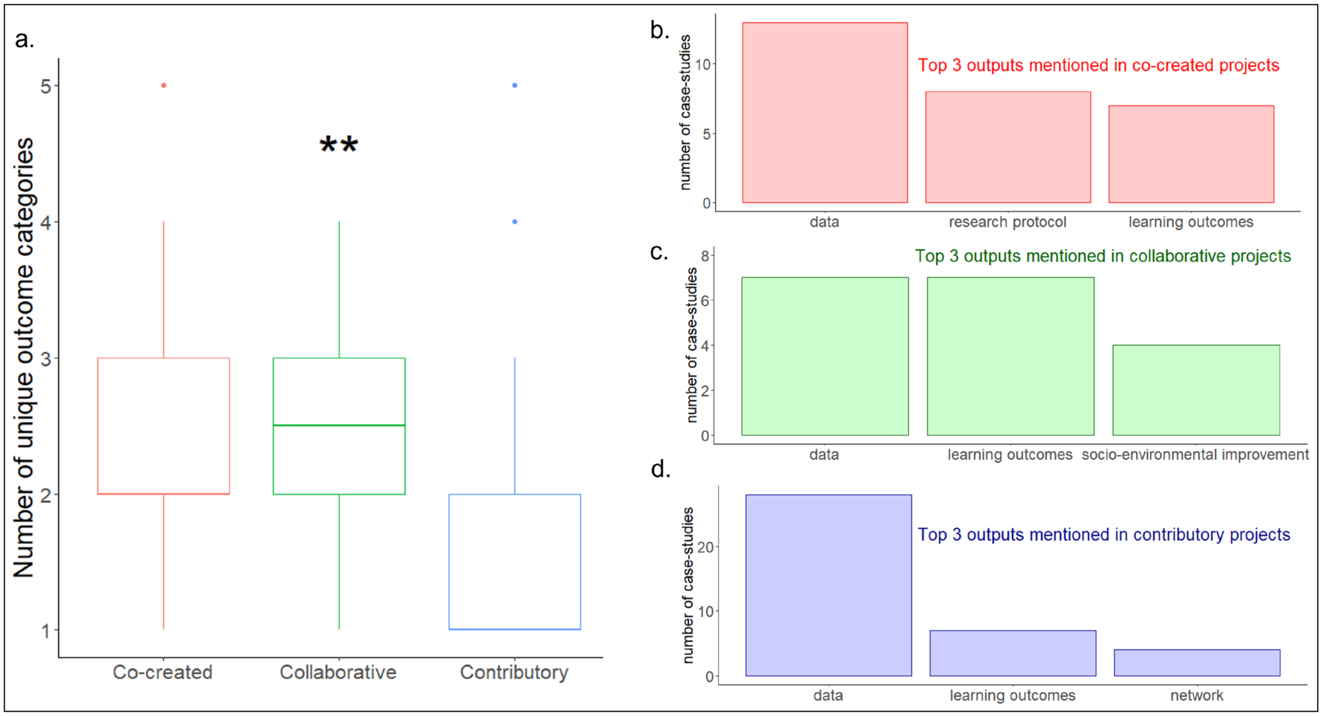

Figure 8 (a) Link between degree of participation and number of unique outcomes (** = $p < 0.01$, Kruskal-Wallis test), and **(b–d)** the top 3 most- mentioned outcomes and their frequencies for **(b)** co-created, **(c)** collaborative, and **(d)** contributory projects.

DISCUSSION

This contribution focuses on understanding how CS projects are implemented, on discussing authorship implications in project design, on the impact of context on project goals, and on the subsequent implications for method selection and how the project's outcomes differ per goal and context. This study links the identified patterns to the potential CS contribution to SDGs in both GN and GS contexts. The findings are complemented with qualitative observations on CS design and implementation challenges as stated by the various authors of the case studies.

In terms of co-authorship, a discrepancy between GN and GS case studies was found, with those implemented in the GN characterized by an almost exclusive authorship from the GN; while in the GS, most projects represent a collaboration between regions. There are also four GS publications that do not include any author with GS affiliation. Strengthening collaborations between GN and GS scientists would allow shifting decision power towards implementation countries, entailing a balance between scientific objectives and local realities (Genda et al. 2022).

Another factor playing a role in setting project goals might be the disciplinary background of authors (Sauermann et al. 2020). While this research did not explore individual profiles, it has been found that co-created projects are typically associated with larger co-author groups. At the same time, co-created projects often include democratization goals, and—together with collaborative projects—appear to present a larger number of unique outcomes per case study than contributory projects.

In fact, co-created projects target contextualized solutions, resulting in benefits for science and society. These are complex projects, requiring partnerships, with all parties trusting scientific and community knowledge as well as demanding intensive communication and open aptitude (Gunnell et al. 2021). Therefore, qualitative research should explore the extent to which the interests of individual authors, research teams (Wray 2016), and communities are balanced.

Given the strong connection between context and goals, a more diverse co-author team is likely to benefit from a more integrative outlook on project design. In this regard, case studies developed by solely GN-affiliated authors could benefit from more diverse teams. Overall, given the diversity in CS projects, mutual exchanges across contexts, disciplines, and backgrounds would enrich CS as a practice. The funding bodies and the geo-political context behind the partnerships were not investigated, but future research could explore how these factors shape CS design. This knowledge would allow a better understanding of how partnerships are built and in which form CS could contribute to SDG 17 (Partnerships for the goals).

Between the GS and GN, major differences in the goals and thematic focus were detected, with GN projects predominantly focusing on biodiversity (SDGs 14 and 15), and GS projects prioritizing agriculture, health, sustainable communities, and climate change (SDGs 2, 3, 11, and 13). The results for the GN align with others that indicate the greatest CS contribution is towards SDG 15 (Fraisl et al. 2020). GS observations align with findings from Pateman, Tuhkanen, and Cinderby (2021) who observe that in low- and middle-income countries, projects could contribute more to SDGs focusing on societal aspects, such as SDG 3 (health) and SDG 11 (sustainable communities) than to environmental SDGs. According to the presented results, these patterns in SDG contributions also align with goal formulation, with the largest group of productivity goals in the GN, and a combination of goals in the GS. It thus appears that the context in which a project is implemented plays an important role in contributing to one or another SDG, as well as the extent to which democratization and productivity goals are both considered in goal formulation.

In addition, although literature provides evidence for the potential contribution of CS to all 17 SDGs (Fraisl et al. 2020; Pateman, Tuhkanen, and Cinderby 2021), not all the SDGs are covered by the analyzed projects in this study. Further research should explore if CS could contribute more easily to specific SDG indicators and how the different nature of CS projects in the GS and GN impact the contribution possibilities.

The patterns in goal setting in the GS and GN are not only relevant when evaluating if and how CS can contribute to SDGs, but also appear connected to methodological design choices and outcomes. Projects with purely productivity goals (such as environmental data collection) tend to apply to contributory projects. When described, these projects often have deliberate productivity-focused recruitment or self-selection of participants, often resulting in the "general public" or "community members with a particular skill or profile." This is in contrast with projects that include democratization goals, characterized by deliberate recruitment and engagement of affected community members. This contrast should be considered in future project design as the lack of participant diversity is a major challenge in supporting sustainability transitions through CS (Sauermann et al. 2020). When targeting participants with different profiles, specifically from underrepresented communities, selecting the right recruitment form is important (Pateman, Dyke, and West 2021).

A final linkage was made between the goal and the outcomes whereby productivity-related goals often translate in the outcome "data," regardless of implementation location. Less tangible outcomes such as "empowerment" and "socio-environmental improvements" are rarer, mostly centered in the GS and commonly including a democratization viewpoint. As such, the results correlate with the two most reported CS outcomes in literature, notably related to "science and technology" and "society" (Wehn et al. 2021).

Finally, in the analyzed case studies, educational outcomes are often assumed rather than demonstrated. However, projects that are not explicitly designed for educational outputs might not necessarily achieve them (Bonney et al. 2016; Roche et al. 2020), indicating the importance of monitoring those outcomes. Conversely, since results are limited by the information provided by the case study authors, less tangible outcomes might have been overlooked by project managers and thus not presented in this analysis.

Case study authors, regardless of the context and the specific goals of each project, acknowledge the benefit of integrating productivity and democratization goals. However, many of them mention clear challenges in balancing these respective goals, such as project constraints, limited resources, and the need for interests alignment (Paul and Palfinger 2020; MacLeod and Scott 2021; Skroblin et al. 2022). Major reflections on societal aspects relate to sense of ownership (Regmi et al. 2019), respect for established social structures (Paul et al. 2020), and local needs and beliefs (Rodrigues et al. 2020). For productivity projects, one of the major challenges is satisfying scientific data needs, ensuring high data quality and sustained public participation (Carleton et al. 2020). Finally, the qualitative review also gleaned successful examples of collecting data while benefiting the society and valuing local knowledge (Rodrigues et al. 2020; Skroblin et al. 2022), demonstrating the potential of successfully integrating productivity and democratization goals.

Limitations of the study

Firstly, the case studies database does not cover the large contextual diversity within countries grouped either as GN or GS. Furthermore, the results of this study fully depend on the information detailed by the respective authors in their publications. Project characteristics were not always described, reducing the number of case studies that could be systematically analyzed.

CONCLUSIONS

This paper outlines how context is often linked to CS project goal formulation and the potential contributions to the SDGs. In the GN, the patterns are dominated by productivity-focused CS projects potentially linking to the SDGs related to biodiversity. In the GS, most projects include a democratization component, and projects thematically link more with SDGs related to well-being and climate change. These goals in turn often translate in methodological choices in terms of participant selection, participant profile, and degree of participation.

Likewise, a strong alignment between goals and outcomes could be detected. While case study authors acknowledge the benefits of combining productivity and democratization goals, challenges in integrating different interests, exacerbated by project constraints and limited resources remain. This paper presents how CS partnerships impact project design and outcomes, concluding that larger teams are typically associated with co-created projects which in turn focus on democratization or democratization and productivity goals, and produce a wide diversity of outcomes.

Understanding how CS dimensions relate by finding patterns in project design highlights the relevance of contextualizing CS projects while balancing societal and scientific goals. This is also important for strengthening the potential CS contribution to the SDGs by collecting monitoring data and/ or contextualizing sustainability transitions.

DATA ACCESSIBILITY STATEMENT

The data used in the research is available in Supplemental File 5: Appendix E. This document includes all the case studies classified according to the instrument (Figure 2).

SUPPLEMENTARY FILES

The supplementary files for this article can be found as follows:

- **Supplemental File 1.** Appendix A. Inclusion/exclusion criteria. DOI: https://doi.org/10.5334/cstp.570.s1
- **Supplemental File 2.** Appendix B. List of GN and GS countries. DOI: https://doi.org/10.5334/cstp.570.s2
- **Supplemental File 3.** Appendix C. Search string. DOI: https://doi.org/10.5334/cstp.570.s3
- **Supplemental File 4.** Appendix D. PRISMA diagrams. DOI: https://doi.org/10.5334/cstp.570.s4
- **Supplemental File 5.** Appendix E. Data used in the research project: Categorization of GN and GS case studies. DOI: https://doi.org/10.5334/cstp.570.s5
- **Supplemental File 6.** Appendix F. Additional Figures. DOI: https://doi.org/10.5334/cstp.570.s6

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

AAC and LJ elaborated the content conception and design, with input from WvP and MD. Data collection by AAC, analysis by LJ and AAC, writing by AAC with contribution of LJ. Editing by LJ and AAC. The conducted research has been supervised by WvP, MD and LJ. All authors contributed to critical revision of the article and have provided approval of the version to be published.

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